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THE TAXONOMICAL OUTLINE OF CHAETOGNATHA¹⁾

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The monographic work by RITTER-ZÁHONY (1911) "Revision der Chätognathen" appeared in the report of the Deutsche Südpolar-Expedition, 1901-3, may be regarded as the base for the taxonomy of Chaetognatha which has been accepted so far. In that paper, the following 27 species belonging to 6 genera were given, besides 16 species were listed as *species incertae*. And other 44 names were treated there as synonyms of valid species.

List 1. Valid species listed by RITTER-ZÁHONY (1911).

- | | |
|-----------------------------------|------------------------------------|
| 1. <i>Sagitta hexaptera</i> | 15. <i>Sagitta neglecta</i> |
| 2. <i>Sagitta maxima</i> | 16. <i>Sagitta regularis</i> |
| 3. <i>Sagitta lyra</i> | 17. <i>Sagitta minima</i> |
| 4. <i>Sagitta gazellae</i> | 18. <i>Sagitta decipiens</i> |
| 5. <i>Sagitta enflata</i> | 19. <i>Sagitta planctonis</i> |
| 6. <i>Sagitta setosa</i> | 20. <i>Sagitta macrocephala</i> |
| 7. <i>Sagitta elegans</i> | 21. <i>Pterosagitta draco</i> |
| 8. <i>Sagitta bipunctata</i> | 22. <i>Spadella cephaloptera</i> |
| 9. <i>Sagitta robusta</i> | 23. <i>Spadella schizoptera</i> |
| 10. <i>Sagitta helenae</i> | 24. <i>Eukrohnia hamata</i> |
| 11. <i>Sagitta friderici</i> | 25. <i>Eukrohnia fowleri</i> |
| 12. <i>Sagitta bedoti</i> | 26. <i>Heterokrohnia mirabilis</i> |
| 13. <i>Sagitta pulchra</i> | 27. <i>Krohnitta subtilis</i> |
| 14. <i>Sagitta serratodentata</i> | |

List 2. *Species incertae* by RITTER-ZÁHONY (1911).

- | | |
|-------------------------------|---------------------------------|
| *1. <i>Sagitta britannica</i> | *7. <i>Sagitta helgolandica</i> |
| *2. <i>Sagitta coreana</i> | *8. <i>Sagitta hispida</i> |
| 3. <i>Sagitta darwini</i> | *9. <i>Sagitta levis</i> |
| 4. <i>Sagitta diptera</i> | *10. <i>Sagitta longicauda</i> |
| *5. <i>Sagitta euxina</i> | *11. <i>Sagitta orientalis</i> |
| *6. <i>Sagitta gegenbauri</i> | *12. <i>Spadella profunda</i> |

1) Contributions from the Seto Marine Biological Laboratory, No. 430.

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|-----------------------------|-----------------------------|
| 13. <i>Sagitta rostrata</i> | 15. <i>Sagitta triptera</i> |
| *14. <i>Sagitta tenuis</i> | 16. <i>Krohnia viridis</i> |

Of the *species incertae*, *S. darwini*, *S. diptera* and *S. triptera* were referred to *S. hexaptera* with some questions and so was *S. rostrata* to *S. setosa*. And *K. viridis* is AIDA's misrecord for *Krohnitta pacifica*. Then eleven species marked with asterisk were left without being referred to any valid species. Forty-one years later, I made a general review on chaetognaths of the Indo-Pacific (Chaetognaths of the Indo-Pacific; Annot. Zool. Japon., Vol. 25, Nos. 1-2, 1952, pp. 307-316) and there were enumerated the world chaetognaths as follows.

List 3. Valid taxa listed by TOKIOKA (1952).

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|---|---|
| 1. <i>Bathyspadella edentata</i> | 24. <i>Sagitta lyra</i> |
| 2. <i>Eukrohnia hamata</i> | 25. <i>Sagitta macrocephala</i> |
| 3. <i>Heterokrohnia mirabilis</i> | 26. <i>Sagitta minima</i> |
| 4. <i>Krohnitta pacifica</i> | 27. <i>Sagitta neglecta</i> |
| 5. <i>Krohnitta subtilis</i> | 28. <i>Sagitta oceanica</i> |
| 6. <i>Krohnittella boureei</i> | 29. <i>Sagitta parva</i> |
| 7. <i>Pterosagitta draco</i> | 30. <i>Sagitta planctonis</i> |
| 8. <i>Sagitta bedfordii</i> | 31. <i>Sagitta pulchra</i> |
| 9. <i>Sagitta bedoti</i> | 32. <i>Sagitta regularis</i> |
| 10. <i>Sagitta bedoti</i> f. <i>minor</i> | 33. <i>Sagitta robusta</i> |
| 11. <i>Sagitta bipunctata</i> | 34. <i>Sagitta serratodentata atlantica</i>
f. <i>typica</i> |
| 12. <i>Sagitta bombayensis</i> | 35. <i>Sagitta serratodentata atlantica</i>
f. <i>pseudoserratodentata</i> |
| 13. <i>Sagitta crassa</i> | 36. <i>Sagitta serratodentata atlantica</i>
f. <i>tasmanica</i> |
| 14. <i>Sagitta crassa</i> f. <i>naikaiensis</i> | 37. <i>Sagitta serratodentata pacifica</i> |
| 15. <i>Sagitta decipiens</i> | 38. <i>Sagitta setosa</i> |
| 16. <i>Sagitta delicata</i> | 39. <i>Sagitta tropica</i> |
| 17. <i>Sagitta elegans</i> | 40. <i>Sagitta tumida</i> |
| 18. <i>Sagitta enflata</i> | 41. <i>Spadella cephaloptera</i> |
| 19. <i>Sagitta euxina</i> | 42. <i>Spadella schizoptera</i> |
| 20. <i>Sagitta ferox</i> | |
| 21. <i>Sagitta friderici</i> | |
| 22. <i>Sagitta helenae</i> | |
| 23. <i>Sagitta hexaptera</i> | |

These forty-two taxa included 37 species, 1 subspecies and 4 forms. Besides, next 11 species were treated as doubtful species.

List 4. Doubtful species by TOKIOKA (1952).

- | | |
|-----------------------------|------------------------------|
| 1. <i>Eukrohnia fowleri</i> | 3. <i>Sagitta levis</i> |
| 2. <i>Sagitta coreana</i> | 4. <i>Sagitta longicauda</i> |

- | | |
|---------------------------------|------------------------------|
| 5. <i>Sagitta maxima</i> | 9. <i>Spadella musculosa</i> |
| 6. <i>Sagitta orientalis</i> | 10. <i>Spadella profunda</i> |
| 7. <i>Sagitta tenuis</i> | 11. <i>Zahonya cestoda</i> |
| 8. <i>Spadella moretonensis</i> | |

Sagitta gazellae was regarded there as a synonym of *S. lyra*. Of the remaining eleven forms of the List 2, *S. euxina* was accepted as a valid species and *S. hispida* was treated as a synonym of *S. ferox*, while *Spadella musculosa* treated by RITTER-ZÁHONY as a synonym of *S. cephaloptera* was regarded then as a doubtful species possibly distinct from *S. cephaloptera*. *Sagitta britannica*, *S. gegenbauri* and *S. helgolandica* were put outside the consideration, as the original descriptions were inaccessible to me. Actually, even if those descriptions are read by myself, I won't be able to give any more comments on those vaguely defined forms than RITTER-ZÁHONY did long ago. Fifteen synonyms appeared after the publication of RITTER-ZÁHONY's monograph were respectively referred to the species considered to be valid, although the following two papers were overlooked at that time: HSÜ's paper (1943) including a new species, *Sagitta multidentata* (non KROHN, 1853), and MAWSON's paper (1944) reporting two new species of *Spadella*, *S. sheardi* and *S. johnstoni*.

Many important papers have been published since the above-mentioned lists were prepared by me, and these have brought a significant number of alternations and additions to the list of the world's chaetognaths. PIERCE's works (1951, 53, 58 and 62) cleared the validity of *Sagitta hispida* and *Sagitta tenuis*, and this was confirmed by subsequent papers by TOKIOKA (1955), SUÁREZ (1955 and 60), FURNESTIN (1959, 60 and 62c) and BAINBRIDGE (1960). DAVID studied the morphology and distribution of the chaetognaths occurring in the Antarctic and adjacent seas and ascertained that *Sagitta gazellae* (1955) and *Sagitta zetesios* (1956) are valid species. Besides, he found two new species from the Antarctic waters: *Sagitta marri* (1956) and *Eukrohnia bathyantartica* (1958). It was found that the individuals which had been known from the warm-water regions under the name of *Sagitta gazellae* were really the *gazellae*-forms of *Sagitta lyra* probably representing the younger stages of that species. This is very interesting when the matter is noted in relation to the life cycle of *Sagitta lyra* suggested by FURNESTIN (1962a). FURNESTIN (1958 and 62b) examined *Sagitta euxina* from the Black Sea and *Sagitta setosa* from the North Sea, the Mediterranean Sea and the Black Sea and concluded that the former should be treated as a variety of the latter. On the other hand, the validity of *Sagitta maxima* and *Eukrohnia fowleri* has been recognized by various authors (DAVID, 1958 a and b). Especially, ALVARIÑO (1962) found out a marked difference of the arrangement of the nerve cord between *S. maxima* and *S. lyra* and put a period to the questions concerning the validity of *S. maxima*. In addition, the following 14 new species and one form have been described.

1. *Pterosagitta besnardi* VANNUCCI and HOSOE, 1952
2. *Sagitta selkirki* FAGETTI, 1958 b
3. *Sagitta ferox* f. *americana* TOKIOKA, 1959
4. *Sagitta neodecipiens* TOKIOKA, 1959
5. *Sagitta gloriae* PRADO, 1960
6. *Sagitta bierii* ALVARIÑO, 1961
7. *Sagitta euneritica* ALVARIÑO, 1961
8. *Sagitta peruviana* SUND, 1961
9. *Sagitta popovicii* SUND, 1961
10. *Sagitta scrippsae* ALVARIÑO, 1962
11. *Eukrohnia bathypelagica* ALVARIÑO, 1962
12. *Spadella nana* OWRE, 1963
13. *Spadella pulchella* OWRE, 1963
14. *Sagitta johorensis* PATHANSALI & TOKIOKA, 1963
15. *Sagitta demipenna* TOKIOKA & PATHANSALI, 1963

Further, *Spadella cephaloptera* f. *angulata* was raised to the rank of species by TOKIOKA and PATHANSALI (1964).

Taking the above-mentioned amendments and additions into the consideration, 65 taxa listed in next section are considered to be valid in my opinion. Eleven species still remain as doubtful species, while others are treated as synonyms. About three fourths of these taxa belong to the genus *Sagitta*, and thus there is found a high grade of variety in *Sagitta*. Some species resemble one another so closely that they may be better treated as subspecies, varieties or ecological forms of a single species, while in some couples one species may differ from the other so much that if the forms in the preceding case are reasonably treated as species, then it is desirable to prepare some genera to fit in such cases. Thus, the necessity of subdividing the genus *Sagitta* has been recognized. TOKIOKA and PATHANSALI (1963) proposed two subgenera, *Aidanosagitta* and *Serratosagitta*, to cover 18 described taxa, but other about thirty ones are still left confused. An attempt to classify these into some groups is to be made in next section. (cf. ALVARIÑO 1963, 136-141)

As to further classification above the level of the genus, I am aware of so far Family Sagittidae shown in "C. CLAUS-K. GROBBEN: Lehrbuch der Zoologie (1905)" and Family Amiskwiidae WALCOTT given to a single fossil species, and Class Sagittoidea found also in CLAUS-GROBBEN's text-book. It is not known whether Amiskwiidae is included in Sagittoidea or not. The group name Chaetognatha has been used for Order, Class or Phylum. ABRIC (1905) rearranged the species of Chaetognatha known at that time into nine new genera by fin characters and then divided those genera into two groups by the situation of the anus.

Gastroproctidae

Scottochaetus—Given to a form figured by T. SCOTT (1896: Additions to the fauna of the Firth of Forth, Pt. VIII—Annelid parasite of *Sagitta*, Ann. Rep. Fish. Board of Scotland, Vol. 14, p. 165, pl. 4, figs. 16–17) without any name nor descriptions. The fin system consisting of paired fins and caudal fin is completely continuous or adjoining parts of the system are in contact with each other; the separation of the caudal fin from the whole system is foreshown.

Krohnochaetus—Type species is *Krohnia foliaceus* AIDA. This genus resembles the preceding one, but without a continuation between the lateral fins and the caudal fin. Lateral fins are extended on the tail segment as well as on the most part of the trunk.

Lyrochaetus—Type species is *Sagitta lyra* KROHN. Each lateral fin is divided on the trunk, but incompletely.

Sagittochaetus—Given for *Sagitta* auct. The separation of the lateral fin is made completely.

Conantochaetus—Type species is *Spadella schizoptera* CONANT. The separation of the lateral fin occurs at the trunk-tail septum; the tail segment is as long as the trunk; non-pelagic.

Spadellochaetus—Given for *Spadella* auct. and *Krohnia hamata* (MÖBIUS). This genus resembles *Krohnochaetus*, but the part of the lateral fin corresponding to the anterior fin of *Sagittochaetus* is not developed.

Grassiochaetus—Type species is *Sagitta Claparedi* GRASSI. This genus resembles *Spadellochaetus*, but the lateral fins and the caudal fin are continuous to each other.

Dracochaetus—The fin system is similar to that of *Spadellochaetus*; a pair of bristle bundles on lateral sides of the trunk. Three species are included; *Dr. Krohni*, *Dr. Strodtmanni*, *Dr. Vougai* BÉRANECK.

Notoproctidae

Gourretochaetus—Type species is *Spadella Marioni* GOURRET.

This classification is, however, evidently unnatural and the principal characters of respective genera are based on incomplete or inaccurate figures or descriptions; none of actual examinations of real specimens was made. Needless to say about the dorsal situation of the anus for Notoproctidae. Thus, the classification was not accepted by successive authors.

Since that no attempt has been made to establish further classification system of Chaetognatha. So is the case in HYMAN's "The Invertebrates, Vol. V (1959)". Nevertheless, it seems to me unreasonable to leave all the extant genera of Chaetognatha in a single group, because some of the structural differences found between certain genera are considered to be of a significant systematic importance. Thus a proposal of a new classification of Chaetognatha, treated here as a phylum, is presented as follows.

PHYLUM CHAETOGNATHA (LEUCKART, 1894)

† 1. Class Archisagittoidea nov.

Family Amiskwiidae WALCOTT, 1911

Genus *Amiskwia* WALCOTT, 1911

Only a single extinct species *A. sagittiformis* WALCOTT, 1911 is known by

three fossil specimens from the Middle Cambrian of British Columbia. OWRE and BAYER (1962) are skeptical to treat the genus as belonging to Chaetognatha and interpret it as a member of Nemertina, possibly related to forms such as *Nectonemertes*. The body size much larger than in extant forms, the existence of a pair of remarkable cephalic tentacles and the location of the anus near the caudal end of the body are unusual for chaetognaths. Moreover, it is strange that any traces of reproductive organs which are so massive in mature individuals of extant forms are not left on these fossils. I am rather inclined to the opinion of OWRE and BAYER. At the same time, however, I cannot definitely reject the possibility that *Amiskwia* might represent an ancient form of recent chaetognaths, on the basis of the comparison between the so old Cambrian fossils and to-day's chaetognaths. Of the strange features of *Amiskwia* mentioned above, the most important one must be the terminal situation of the anus, and essentially this is not unusual for Chaetognaths as the endodermal septum stretches along the sagittal axis of the body from the pharynx to the caudal end of the body in the larval stage of chaetognaths. Thus, when *Amiskwia* is admitted as a member of Chaetognatha, a special group must be established to hold it, and the group, Class Archisagittoidea is proposed here for it, should be characterized by the location of the anus at the caudal end of the body. Other external features such as the existence of a pair of stout cephalic tentacles and others are regarded as being of the family or generic importance.

2. Class Sagittoidea CLAUS and GROBBEN, 1905

The class consists of extant forms. The anus opens on the ventral side just before the trunk-tail septum, far anterior to the caudal end of the body. Nine genera have been included unless further division of the genus *Sagitta* is made. Of the characteristics differentiating these genera one another, the existence of the ventral transverse musculature and the peculiar appearance of hooks and teeth unique to *Krohnitta* are most remarkable and considered to be of an essential importance. The differences found in the appearance of fins and number of tooth-rows are less significant as is suspected from the ontogenical observations.

Now, there are two groups of chaetognaths differing distinctly from each other in the mode of life; one is the littoral group represented by a few members of *Spadella* and the other is the pelagic group containing a large number of species mostly belonging to the genus *Sagitta* in the sense hitherto be used. Pelagic species are mostly devoid of the ventral transverse musculature and provided with less glandular structures on the body surface, except for a few deep-water forms. Contrarily, members of *Spadella* are all provided with the ventral transverse musculature in the coelom and richer glandular

structures on the body surface. It seems to me that pelagic forms of a simpler body structure were derived from the littoral forms with creeping ability and with more complicated body structures. The reverse process cannot be impossible, but it seems more improbable than the preceding process. For this reason, the existence of the ventral transverse musculature is regarded here as a basic feature separating the primitive forms from the advanced ones, and the peculiarity found in hooks and teeth of *Krohnitta* is considered to be a sign showing a high grade of specialization. Thus, the class is divided into the following three main groups.

1. Order Phragmophora nov. Phragmatic structure made of the ventral transverse musculature in the coelom. Usually various kinds of glandular structures are seen on the body surface, in the neck or cephalic region.

2. Order Aphragmophora nov. Phragmatic structure is absent and thus the whole coelom is entirely hollow. Glandular structures on the body surface are scarcely developed.

1. Suborder Ctenodontina nov. Hooks are curved gently and tooth-rows are comb-shaped, teeth are slender.

2. Suborder Flabellodontina nov. Hooks are curved rather abruptly and teeth are stouter than in Ctenodontina and arranged in a fan shape.

§ **Order Phragmophora** The order is divided into two families.

I. Family Spadellidae nov. Littoral, usually resting on algae, stones or other objects on the bottom, but retaining the ability of creeping and swimming. Tail segment is relatively large. One or two pairs of lateral fins. Anterior and posterior rows of teeth, which show a trend to the degeneration. Corona ciliata on the neck, wider than long.

(1) Genus *Spadella* LANGERHANS, 1880

1. *S. cephaloptera* (BUSCH, 1851)

Sagitta cephaloptera BUSCH, 1851

**Sagitta Batziana* GIARD, 1874

**Sagitta Claparèdi* GRASSI, 1883

**Sagitta gallica* PAGENSTECHER, 1863

**Sagitta Mariana* LEWES, 1858

**Spadella parvula* MOLTSCHANOFF, 1909

**Sagitta pontica* ULJANIN, 1870

2. *S. angulata* (TOKIOKA, 1951)

Spadella cephaloptera f. *angulata* TOKIOKA, 1951

3. *S. moretonensis* JOHNSTON & TAYLOR, 1919

* Synonymy after RITTER-ZÁHONY (1911).

4. *S. schizoptera* CONANT, 1895
5. *S. sheardi* MAWSON, 1944
6. *S. johnstoni* MAWSON, 1944
7. *S. nana* OWRE, 1963
8. *S. pulchella* OWRE, 1963

S. cephaloptera and *S. angulata* are devoid of any adherent apparatus, while other six species have each adherent apparatuses of various shapes. In *S. moretonensis* the apparatuses are rudimentary and arranged asymmetrically. In other five species, the apparatuses are well developed in a paired arrangement. It is not impossible that at least some of the five species, *S. schizoptera*, *S. sheardi*, *S. johnstoni*, *S. nana* and *S. pulchella*, represent only different intra-specific variants of a single species. *Spadella musculosa* and *Spadella profunda* described by DONCASTER in 1903 are left as questionable species. It seems rather dangerous to abandon these deep-water species, as some valid species of *Spadella* are collected from the waters of a considerable depth.

II. Family Eukrohniidae nov. Pelagic, tail segment is comparatively short. One pair of lateral fins, each beginning far anterior to the trunk-tail septum. Anterior tooth-row or both anterior and posterior tooth-rows may be missing in some genera. So far as it is described, the conona ciliata begins at the posterior edge of the brain and ends at the neck region. All valid forms are known from the deep water at least in the warm-water regions.

(2) Genus *Eukrohnia* RITTER-ZÁHONY, 1909

9. *E. hamata* (MÖBIUS, 1875)
Sagitta hamata MÖBIUS, 1875
**Krohnia hamata* var. *borealis* MOLTSCHANOFF, 1907
Eukrohnia hamata var. *antarctica* JOHNSTON & TAYLOR, 1921
Krohnia foliacea AIDA, 1897
Eukrohnia richardii GERMAIN & JOUBIN, 1912
10. *E. fowleri* RITTER-ZÁHONY, 1909
11. *E. bathyantartica* DAVID, 1958
12. *E. bathypelagica* ALVARIÑO, 1962

The last two species are separated from *E. hamata* only by exact differences, although their distributions are said strictly limited.

(3) Genus *Heterokrohnia* RITTER-ZÁHONY, 1911

13. *H. mirabilis* RITTER-ZÁHONY, 1911

(4) Genus *Bathyspadella* TOKIOKA, 193914. *B. edentata* TOKIOKA, 1939

Next two genera, respectively represented by a single species, are placed here provisionally with some doubts.

Genus *Krohnittella* GERMAIN & JOUBIN, 1912*K. boureei* GERMAIN & JOUBIN, 1912Genus *Zahonya* OYE, 1918*Z. cestoda* OYE 1918

Two specimens of *Krohnittella boureei* were collected once from the depths north of the Canary Islands. No descriptions are given for the ventral transverse musculature, the intestinal diverticula, the eye-pigment and the collarette. Thus, the exact situation of this genus is quite obscure. However, one pair of lateral fins, the corona ciliata confined to the head, the complete absence of teeth, and the large depth of the inhabiting layer seem to allege that the genus is allied to genera of Eukrohniidae. It is possible that the existence of the ventral transverse musculature was overlooked. On the dorsal aspect of the head of this species figured by GERMAIN & JOUBIN, no pigment is indicated in each eye. The species resembles *Bathyspadella edentata* in the complete absence of teeth, but differs distinctly from it in that the tail segment is much shorter.

Zahonya cestoda was once collected from the surface water of the eastern Java Sea. The whole trunk and the tail segment are provided with the ventral transverse musculature. The corona ciliata is described to be confined to the head. But it is very probable that the outline of the pharynx was mistaken for the corona ciliata in this case. Other features are quite the same as in general species of Ctenodontina of Aphragmophora. The comment given to this species in my previous paper (1952, p. 312) may be reproduced here again to show a possible interpretation about the species,—“It is a noteworthy fact that some species with strongly developed musculature assume an appearance, when they are in a slightly contracted state, as if they were provided with a transverse musculature along the whole body. Thus, this species is possibly no more than a small individual of *S. robusta* (or *S. ferox*) in such a state.” If this species is proved to be valid, then the habitat, the surface layer in the tropical waters, must be quite unusual for the members of the family.

§ Order Aphragnophora

Suborder Ctenodontina

III. Family Sagittidae CLAUS & GROBBEN 1905 Two pairs of lateral fins. The former genus *Sagitta* is now splitted into next nine genera.

(5) Genus *Sagitta* (s. str.) QUOY & GAIMARD, 1827

The corona ciliata is very elongate, begins just behind the brain and stretches posteriorly onto the dorsal side of the anterior portion of the trunk. Intestinal diverticula are absent. Lateral fins are thoroughly set with rays.

15. *S. bipunctata* QUOY & GAIMARD, 1827
(Based on the description given by RITTER-ZÁHONY, 1911.)
Sagitta californica MICHAEL, 1913
**Spadella Marioni* GOURRET, 1884
**Sagitta multidentata* KROHN, 1853
16. *S. setosa* MÜLLER, 1847
**Sagitta Germanica* LEUCKART, 1847
*?*Sagitta rostrata* BUSCH, 1851
17. *S. setosa* var. *euxina* (MOLTSCHANOFF, 1909)
Sagitta euxina MOLTSCHANOFF, 1909
18. *S. tenuis* CONANT, 1896
Sagitta popovicii SUND, 1961
19. *S. friderici* RITTER-ZÁHONY, 1911
Sagitta eumeritica ALVARIÑO, 1961
Sagitta peruviana SUND, 1961
20. *S. helenae* RITTER-ZÁHONY, 1910
21. *S. bombayensis* LELE & GAE, 1936

S. bipunctata described by some authors in earlier years represent *hexaptera*, *setosa*, *elegans*, *bedoti* or rarely *Spadella cephaloptera*.

As to the distinction between *S. tenuis* and *S. friderici* see TOKIOKA's paper of 1961. In that paper, the proportion of the anterior part of the posterior fin above the trunk-tail septum to the posterior part of the fin below the septum is taken as one of the important clues. Generally the ratio is smaller in *S. tenuis* than in *S. friderici*. It is, however, not impossible that the development of the anterior part of the posterior fin above the septum might be retarded by the fast development of the ovary in the structural connection. More observations and measurements made statistically on various species are desirable to settle this problem.

(6) Genus *Zonosagitta* nov.

The corona ciliata as in *Sagitta* (s. str.), intestinal diverticula absent. Lateral fins are each provided with a very remarkable rayless-zone.

22. *Z. bedoti* (BÉRANECK, 1895)

Sagitta bedoti BÉRANECK, 1895

23. *Z. bedoti* f. *minor* (TOKIOKA, 1942)

Sagitta bedoti f. *minor* TOKIOKA, 1942

Sagitta bedoti minor: HAMON, 1956

?*Sagitta polyodon* DONCASTER, 1902

24. *Z. pulchra* (DONCASTER, 1902)

Sagitta pulchra DONCASTER, 1902

Sagitta weberi OYE, 1918

Z. bedoti f. *minor* from the tropical waters matures at much smaller body size (about 10 mm) than that of mature individuals of the typical form which may be up to 30 mm in higher latitudes, the Yellow Sea or the Japan Sea. Such larger individuals are noted by ALVARIÑO (1963) as *bedoti* f. *large*. Recently, further smaller form of *Z. bedoti* was found by PATHANSALI in certain inlets of Malay Peninsula. This form matures at 6–7 mm and thus may represent a special ecological form of the species; its description will be given in a future paper. The existence of the rayless-zone seems to be a significant character as the fin rays are generated ontogenically at the very beginning of the fin formation and the arrangement of rays is quite regular in adult forms.

(7) Genus *Serratosagitta* TOKIOKA & PATHANSALI, 1963

Originally defined as a subgenus. This genus conforms to *Sagitta* (s. str.) in features concerning the corona ciliata, intestinal diverticula and lateral fins, but differs from the latter in having serrated hooks, much smaller and elongate pigmented area of the eye, seminal vesicles situated just behind the posterior fin and widely apart from the tail fin and a remarkable swelling near the middle of the vas deferens. The serrated aspect of the hook edge is not a very unusual feature for members of Sagittidae, as under high magnification the hook edge manifests sometimes an insignificant array of faint prominences regularly or irregularly arranged in some species, and thus the serrated feature of the hook can not be of a great systematic importance.*

25. *S. serratodentata* (KROHN, 1853)

Sagitta serrato-dentata KROHN, 1853

* This will be mentioned in detail by PATHANSALI in his paper in press.

- **Sagitta serrulata* CLEVE, 1905
- Sagitta serratodentata* f. *atlantica* TOKIOKA, 1940
- Sagitta serratodentata atlantica* f. *typica* TOKIOKA, 1952
- Sagitta serratodentata atlantica* TOKIOKA, 1959
- 26. *S. pseudoserratodentata* (TOKIOKA, 1939)
 - Sagitta pseudoserratodentata* TOKIOKA, 1939
 - Sagitta serratodentata atlantica* f. *pseudoserratodentata* TOKIOKA, 1952
 - Sagitta serratodentata pseudoserratodentata* TOKIOKA, 1959
- 27. *S. tasmanica* (THOMSON, 1947)
 - Sagitta serratodentata tasmanica* THOMSON, 1947
 - Sagitta serratodentata atlantica* f. *tasmanica* : TOKIOKA, 1952
 - Sagitta selkirki* FAGETTI, 1958
- 28. *S. bierii* (ALVARIÑO, 1961)
 - Sagitta bierii* ALVARIÑO, 1961
- 29. *S. pacifica* (TOKIOKA, 1940)
 - Sagitta serratodentata* f. *pacifica* TOKIOKA, 1940
 - Sagitta serratodentata pacifica* : THOMSON, 1947
 - Sagitta pacifica* : BIERI, 1957

S. pacifica was first defined by TOKIOKA as a geographical form of *serratodentata*, but later raised to the rank of subspecies by THOMSON (1947) and then to species by BIERI (1957). *S. bierii* resembles very closely *S. tasmanica*, differing from it only in the exact appearance of the seminal vesicle. As the main distributions of *S. tasmanica* and *S. bierii* are confined to the rather cooler waters of the southern hemisphere or to the northward flows, the Humboldt Current and the affected area off the California coast and the Benguela Current, both originating in the southern cool waters, it is not impossible that these two species are identical with each other. Further studies on the morphology of the seminal vesicle are desirable. On the posterior fin, in some species, rays are sometimes missing in a narrow area around the female genital opening, although this is nearly insignificant.

(8) Genus *Parasagitta* nov.

The corona ciliata as in *Sagitta* (s. str.), lateral fins are wholly set with rays. Intestinal diverticula are present.

- 30. *P. elegans* (VERRILL, 1873)
 - Sagitta elegans* VERRILL, 1873
 - **Sagitta falcidens* LEIDY, 1882
 - Sagitta flaccida* GALZOW, 1909
 - **Sagitta germanica* of some authors
 - **Sagitta glacialis* MOLTSCHANOFF, 1907
 - **Sagitta gracilis* VERRILL, 1885

**Sagitta melanognatha* MOLTSCHANOFF, 1907

**Sagitta rapax* MOLTSCHANOFF, 1907

31. *P. elegans arctica* (AURIVILLIUS, 1896)

Sagitta arctica AURIVILLIUS, 1896

This subspecies consists of larger individuals from the far off-shore waters in the subarctic to the arctic regions. The difference between this and typical *elegans* does not seem to be discontinuous. However, this subspecific distinction may be effectual when the chaetognath populations in those areas are discussed at the level of stocks.

32. *P. elegans baltica* (RITTER-ZÁHONY, 1911)

Sagitta elegans f. *baltica* RITTER-ZÁHONY, 1911

Besides the above-mentioned subspecific differentiations, the diminution of the body size of mature individuals in the enclosed environments is recorded in Lake Ogac on the north-eastern coast of Canada (DUNBAR, 1962).

33. *P. hispida* (CONANT, 1895)

Sagitta hispida CONANT, 1895

Sagitta gloriae PRADO, 1960

34. *P. hispida americana* (TOKIOKA, 1959)

Sagitta ferox f. *americana* TOKIOKA, 1959

Anterior teeth are more numerous than in the typical form.

35. *P. robusta* (DONCASTER, 1902)

Sagitta robusta DONCASTER, 1902

Sagitta ai TOKIOKA, 1939

Sagitta ferox: ALVARIÑO, 1962

36. *P. ferox* (DONCASTER, 1902)

Sagitta ferox DONCASTER, 1902

Sagitta equatoria GRAY, 1923

Sagitta hispida of some authors

Sagitta japonica GALZOW, 1909

Sagitta robusta of many authors

I think the identification of *P. ferox* and *P. robusta* should be made after the description by THOMSON (1947) based on the type specimens of DONCASTER. *P. hispida* resembles these two species very closely, but differs from them in the exact appearance and situation of the seminal vesicle and number of teeth. *Sagitta gloriae* from Brazilian waters is considered to be a synonym of *P. hispida*.

(9) Genus *Aidosagitta* TOKIOKA & PATHANSALI, 1963

The genus was originally defined as a subgenus. The corona ciliata begins

below the level of eyes, intestinal diverticula are present, and lateral fins are wholly rayed. The seminal vesicle is generally situated just behind the posterior fin, being apart more or less from the base of the tail fin; in no species is the anterior glandular portion differentiated externally. The tail segment is relatively long. In most species, the distribution is limited to the inlet or neritic waters.

37. *A. neglecta* (AIDA, 1897)
Sagitta neglecta AIDA, 1897
**Sagitta septata* DONCASTER, 1902
Sagitta trichodermis OYE, 1918
38. *A. oceanica* (GRAY, 1930)
Sagitta oceanica GRAY, 1930
Sagitta lacunae TOKIOKA, 1942
39. *A. johorensis* (PATHANSALI & TOKIOKA, 1963)
Sagitta johorensis PATHANSALI & TOKIOKA, 1963
40. *A. regularis* (AIDA, 1897)
Sagitta regularis AIDA, 1897
41. *A. bedfordii* (DONCASTER, 1902)
Sagitta Bedfordii DONCASTER, 1902
Sagitta pseudoregularis OYE, 1918
42. *A. demipenna* (TOKIOKA & PATHANSALI, 1963)
Sagitta (Aidanosagitta) demipenna TOKIOKA & PATHANSALI, 1963
43. *A. crassa* (TOKIOKA, 1938)
Sagitta crassa TOKIOKA, 1938
Sagitta multidentata HSÜ, 1943
44. *A. crassa* f. *naikaiensis* (TOKIOKA, 1939)
Sagitta crassa f. *naikaiensis* TOKIOKA, 1939
45. *A. crassa* f. *tumida* (TOKIOKA, 1939)
Sagitta tumida TOKIOKA, 1939
46. *A. delicata* (TOKIOKA, 1939)
Sagitta delicata TOKIOKA, 1939
47. *A. tropica* (TOKIOKA, 1942)
Sagitta tropica TOKIOKA, 1942
48. *A. parva* (OYE, 1918)
Sagitta parva OYE, 1918

A. oceanica is related very closely to *A. neglecta*, the comparison between these two species is fully discussed in the description of *S. lacunae*. I made observations on the chaetognath population of Lake Notoro of Hokkaidô Island in early September last year and in early May this year and confirmed that the chaetognath population of this lake, completely separated from the Okhotsk

Sea by a sand bank in the winter season but communicated with the sea through a narrow and shallow canal maintained artificially during the summer season, consisted of only a single species which had been known under the name of *Sagitta tumida* and that the species assumed the characteristic appearance of *S. tumida* in May, but the appearance was exactly the same as that of *A. crassa* f. *naikaiensis* in September. This seems to prove that *S. tumida* is an ecological form of *A. crassa* and the appearance characteristic to *S. tumida* is the feature unique to the generation appeared after the winter. Further details will be given in a future paper.

(10) Genus *Mesosagitta* nov.

The corona ciliata begins on the neck and stretches posteriorly onto the anterior portion of the trunk. Intestinal diverticula are present. Fin rays are sparse, or missing in some parts of lateral fins. The posterior fin lies much more along the trunk than along the tail. Seminal vesicles are situated apart from the rear end of the posterior fin. Generally the members of the genus occur most frequently and abundantly in mesoplankton, although they can be fished sparsely in the surface layer.

49. *M. minima* (GRASSI, 1881)

Sagitta minima GRASSI, 1881

? *Sagitta atlantica* GRAY, 1923

50. *M. decipiens* (FOWLER, 1905)

Sagitta decipiens FOWLER, 1905

Sagitta philippini MICHAEL, 1919

Sagitta Sibogae FOWLER, 1906

51. *M. neodecipiens* (TOKIOKA, 1959)

Sagitta neodecipiens TOKIOKA, 1959

The difference between *decipiens* and *neodecipiens* is found merely in the situation of the seminal vesicle. More crucial studies are needed till the validity of *neodecipiens* is confirmed definitely.

(11) Genus *Solidosagitta* nov.

The appearance of the corona ciliata, the existence of intestinal diverticula, and the distribution of the posterior fin on the trunk and the tail are quite similar to those in the preceding genus. In the present genus, however, the distinct rayless-zone is defined on respective fins and the pigmented area of the eye is markedly small as compared with the size of the eye. The body is much stouter than in the preceding genus. All members occur in the middle to deep layers of the sea. This genus is related to *Mesosagitta* very closely.

General body features and the inhabiting layer are quite similar in these two genera which might be better united into a single genus.

- 52. *S. planctonis* (STEINHAUS, 1896)
Sagitta planctonis STEINHAUS, 1896
? *Sagitta moreauensis* GRAY, 1923
- 53. *S. zetesios* (FOWLER, 1905)
Sagitta Zetesios FOWLER, 1905
- 54. *S. marri* (DAVID, 1956)
Sagitta marri DAVID, 1956

(12) Genus *Caecosagitta* nov.

The central nuclear and the peripheral cortical regions are not differentiated in the eye, hence no pigments are found there. Lateral fins are nearly wholly rayed. Intestinal diverticula are absent. A single species from the deep water.

- 55. *C. macrocephala* (FOWLER, 1905)
Sagitta macrocephala FOWLER, 1905

(13) Genus *Flaccisagitta* nov.

The body is flaccid without exception. The corona ciliata is short and confined to the head, starting just behind the brain and stretching to the neck. Intestinal diverticula absent. There is a distinctive rayless-zone on each lateral fin.

- 56. *F. hexaptera* (D'ORBIGNY, 1834-44)
Sagitta hexaptera D'ORBIGNY, 1834-44
**Sagitta exaptera* D'ORBIGNY, 1834-44
*? *Sagitta darwini* GRASSI, 1883
*? *Sagitta diptera* D'ORBIGNY, 1834-44
Sagitta fowleri BENHAM, 1912
**Sagitta longidentata* GRASSI, 1881
**Sagitta magna* LANGERHANS, 1880
Sagitta hexaptera f. *magna* GERMAIN & JOUBIN, 1916
**Sagitta Mediterranea* FORBES, 1843
**Sagitta tricuspidata* KENT, 1870
**Sagitta triptera* D'ORBIGNY, 1834-44
- 57. *F. enflata* (GRASSI, 1881)
Sagitta enflata GRASSI, 1881
Sagitta inflata RITTER-ZÁHONY, 1908
**Sagitta australis* JOHNSTON, 1909
**Sagitta brachycephala* MOLTSCHANOFF, 1907
**Sagitta flaccida* CONANT, 1896

58. *F. gardineri* (DONCASTER, 1902)
Sagitta gardineri DONCASTER, 1902
Sagitta inflata, *gardineri*-type: RITTER-ZÁHONY, 1909
Sagitta inflata f. *gardineri*: TOKIOKA, 1959
59. *F. lyra* (KROHN, 1853)
Sagitta lyra KROHN, 1853
**Sagitta furcata* STEINHAUS, 1896
Pseudosagitta grimaldii GERMAIN & JOUBIN, 1912
60. *F. scrippsae* (ALVARIÑO, 1962)
Sagitta scrippsae ALVARIÑO, 1962
61. *F. gazellae* (RITTER-ZÁHONY, 1909)
Sagitta gazellae RITTER-ZÁHONY, 1909
62. *F. maxima* (CONANT, 1896)
Spadella maxima CONANT, 1896
**Sagitta gigantea* BROCH, 1906
**Sagitta Whartoni* FOWLER, 1896

Smaller mature individuals of *F. inflata* were ever separated from those of usual body size (*forma typica*) by RITTER-ZÁHONY* (1909, p. 47) and named *forma minor*. This distinction will be significant if occurrences of these two forms are separated from each other. *F. gardineri* differs from *inflata* in having longer ovaries, while the length of mature ovary seems quite discontinuous between these two species. In some individuals of *F. lyra* the arrangement of lateral fins resembles closely that of *F. gazellae*, the anterior and posterior fins not being combined with each other by a low rayless elevation. Such individuals are *gazellae*-forms of *F. lyra* and distinctly differ from genuine *F. gazellae* (see p. 337). *F. scrippsae* is related very closely to *F. lyra*, but it is said that the species is provided with a distinctive collarette around the neck. This feature is quite exceptional for members of this genus. If the existence of the collarette is ascertained by successive authors, then this species must be recognized as a distinct species, as the distribution is confined to the sub-arctic waters of the North Pacific.

IV. Family Pterosagittidae nov. One pair of lateral fins, each beginning at the trunk-tail septum. The massive collarette is developed along the body sides, and there is a tuft of small tentacular protuberances on each lateral side at the level of the ventral ganglion.

(14) Genus *Pterosagitta* COSTA, 1869

The corona ciliata is oval, longer than wide, and stretched below the level

* RITTER-ZÁHONY, R. (1909): Chätognathen. Zool. Ergebn. d. Exped. S.M.S. Pola in das Rote Meer 1895-1898. Denkschr. Akad. Wiss. Wien, Vol. 84. (Through RITTER-ZÁHONY, 1910).

of the neck. Lateral fins are rayed thoroughly.

63. *P. draco* (KROHN, 1953)

Sagitta draco KROHN, 1853

Pterosagitta besnardi VANNUCCI & HOSOE, 1952

Dracochaetus Krohni ABRIC, 1905

**Pterosagitta mediterranea* A. COSTA, 1869

Dracochaetus Strodtmanni ABRIC, 1905

**Spadella Vougai* BÉRANECK, 1895

Suborder Flabellodontina

V. Family Krohnittidae nov. One pair of lateral fins, each beginning above the trunk-tail septum. The shape of the tail fin differs slightly from that in other families.

(15) Genus *Krohmitta* RITTER-ZÁHONY, 1910

The corona ciliata is short and begins at the level of the neck. Distinct rayless-zone is found on the lateral fin.

64. *K. subtilis* (GRASSI, 1881)

Sagitta Suptilis GRASSI, 1881

65. *K. pacifica* (AIDA, 1897)

Krohmia pacifica AIDA, 1897

Krohmitta kerberti OYE, 1918

Krohmia viridis AIDA, 1897

In all, 5 families, 15 genera and 65 taxa are included in Class Sagittoidea. Of 65 taxa, three are defined as subspecies, one as variety and three as forma, thus 58 are recognized as species. The type species of respective genera are represented by the first one of the species list, and the same as to the families. The establishment of forma, variety or subspecies based on minute morphological differences and the separation of species due to so exact differences found in the body appearance may be accused for their making the taxonomy of Chaetognatha complicated. Nevertheless, such distinctions must be very significant when they are noted in relation to the speciation of Chaetognatha or to the distribution of water masses in oceans. Apart from the problems of ranking these taxa, further efforts are desirable to confirm such exact morphological differences and to clarify the causes of such variations.

The following eleven species are still left as doubtful species.

1. *Sagitta britannica* FORBES, 1843

2. *Sagitta gegenbauri* FOL, 1879

3. *Sagitta helgolandica* R. LEUCKART, 1857

4. *Sagitta coreana* MOLTSCHANOFF, 1907

5. *Sagitta levis* GALZOW, 1909
6. *Sagitta longicauda* GALZOW, 1909
7. *Sagitta orientalis* MOLTSCHANOFF, 1907
8. *Spadella musculosa* DONCASTER, 1903 (see p. 342)
9. *Spadella profunda* DONCASTER, 1903 (see p. 342)
10. *Zahonyia cestoda* OYE, 1918 (see p. 343)
11. *Krohnittella boureei* GERMAN & JOUBIN, 1912 (see p. 343)

As stated in my previous paper (1952, pp. 311-312) *Sagitta longicauda* is related closely to *Aidanosagitta crassa* and *Sagitta coreana* and *S. levis* resemble *f. naikaiensis* of the same species, while *S. orientalis* and again *S. levis* bear some resemblances to *Parasagitta elegans*. Anyhow, the reexamination of type specimens is the only way to solve the questions about these species.

Before closing this taxonomical note on Chaetognatha, I want to express here my hearty thanks to Dr. T. KOMAI, professor emeritus of Kyoto University, who offered me the theme "the systematic study of Chaetognatha" when I graduated from the Zoological Institute of Kyoto University and was going to the former Mitsui Institute of Marine Biology twenty-eight years ago and since then has encouraged me and also given me adequate advices at times. But for his kind teaching and help in earlier stages of this study, I would not be able to reach the present level to propose here a new taxonomical system of Chaetognatha. (1964, 11, 20)

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